SEMI-ANNUAL REPORT

NASA CONTRACT NAS 5-31368

For
MODIS Team Member: Steven W. Running
Assoc. Team Member: Ramakrishna R. Nemani

15 January 2004
Edits 17 Feb

OBJECTIVES:

We have defined the following near-term objectives for our MODIS contract:
- Test software for our MODIS products, #15 Leaf Area Index and Fraction Absorbed Photosynthetically Active Radiation, #16 Evapotranspiration from land surface, and #17 Daily Photosynthesis Annual Net Primary Production as MODAPS processing delivers global datasets.

- Deliver software for the Aqua MODIS sensor, for MOD 15, MOD 17 and the new MOD 16, Surface Evaporation Index

- Develop MODIS applications products for national natural resource management.

- Organization of a validation effort using AMERIFLUX fluxnet sites to correlate and test the MODIS derived LAI and Net Primary Production.

The NTSG lab currently employs:
Dr. Steven Running, Director and Professor,
Dr. Ramakrishna Nemani, Research Assoc. Professor
Dr. John Kimball, Research Assistant Professor
Dr. Sinkyu Kang, Postdoctoral Research Associate
Dr. Maosheng Zhao, Postdoctoral Research Associate
Dr. Faith Ann Heinsch, Postdoctoral Research Associate
Dr. Qiaozhen Mu, Postdoctoral Research Associate
Mr. Andrew Neuschwander, Programmer/Sys Admin
Mr. Saxon Holbrook, Computer Systems Engineer
Mr. Andy Michealis (Student Programmer)
Mr. Matt Reeves, PhD student
Mr. W. Matt Jolly, PhD student
Ms. Pat Andrews, PhD student
Ms. Rachel Loehman, PhD student
Ms. Cristina Milesi, PhD student
Ms. Ann Radil, MS student

Ms. Alana Oakins, MS student
Mr. David Mildrexler, MS student
Mr. Matt Jones, MS student
Ms. Youngee Cho, Fiscal Manager

All of these members contribute to certain aspects of our MODIS work.

ACTIVITIES of Steven W. Running, Principal Investigator

Along with the normal array of conference presentations, I am working on two NRC committee reports concerning the evolution of EOS science in the future NPOESS environment. These reports will be out in 2004. I also spent a lot of time writing text for the North American Carbon Program Science Implementation Strategy. This draft document has not yet been finalized and publicly released.

I finished a major overview paper for Bioscience on the MODIS Gross Primary Production/Net Primary Production dataset.

Running S. W., R. R. Nemani1, F. A. Heinsch, M. *Zhao, M*. Reeves, H. Hashimoto 2004. A continuous Satellite-derived measure of global terrestrial primary productivity: Future science and applications. Bioscience (in press)

Other Research Activity, Invited Conference Attendance:

AGU Fall Meeting, San Francisco, December 2003
Committee on Environmental Satellite Data Utilization (CESDU) meeting, Washington DC, September 2003
NRC Committee on Environmental Satellite Data Utilization (CESDU) meeting, Irvine, CA, December 2003
30th International Symposium on Remote Sensing of Environment, Honolulu, HI, November 2003
AmeriFlux Annual Meeting, Denver, CO, October 2003
Carbon Cycle and Carbon Sequestration Program (TCP) meeting Denver, CO, October 2003
NRC Committee on Earth Studies (CES) meeting, Washington DC, October 2003
NASA Modland meeting, Baltimore, MD, July 2003
International GeoScience & Remote Sensing Symposium (IGARSS) 2003 meeting, Toulouse, France July 2003

# ACTIVITIES of Ramakrishna Nemani (Associate Team Member)

MODIS Net primary production (MOD17)

Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999.
Ramakrishna R. Nemani, Charles D. Keeling, Hirofumi Hashimoto, William M. Jolly, Stephen C. Piper, Compton J. Tucker, Ranga B. Myneni, Steven W. Running. Science, 300, 1560, 2003 (June 6th)
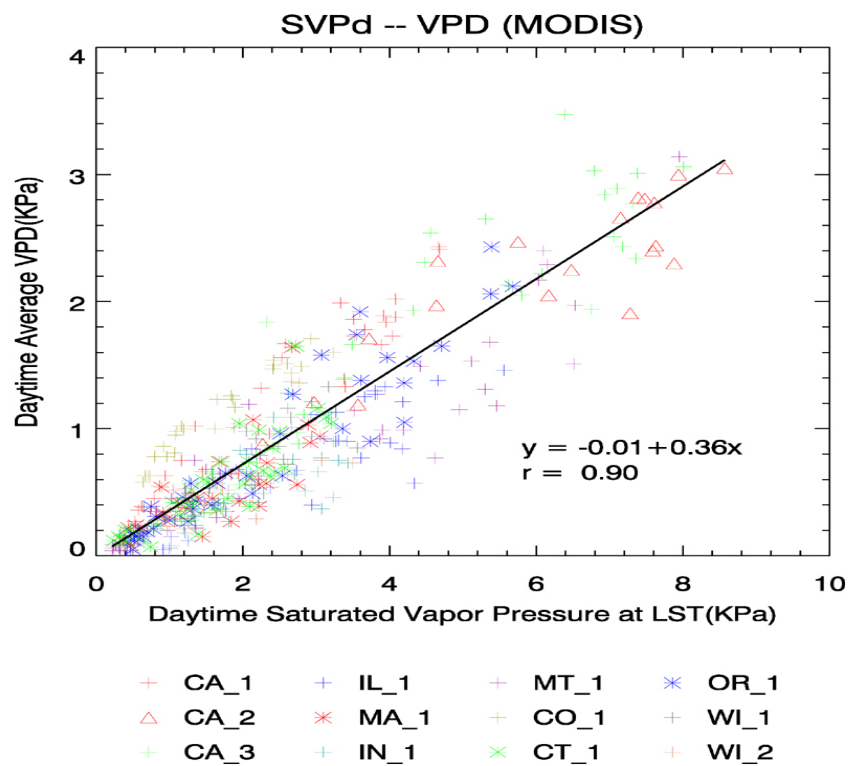
Recent climatic changes have enhanced plant growth in northern mid-latitudes and high latitudes. However, a comprehensive analysis of the impact of global climatic changes on vegetation productivity has not before been expressed in the context of variable limiting factors to plant growth. We present a global investigation of vegetation responses to climatic changes by analyzing 18 years (1982 to 1999) of both climatic data and satellite observations of vegetation activity. Our results indicate that global changes in climate have eased several critical climatic constraints to plant growth, such that net primary production increased 6% (3.4 petagrams of carbon over 18 years) globally. The largest increase was in tropical ecosystems. Amazon rain forests accounted for 42% of the global increase in net primary production, owing mainly to decreased cloud cover and the resulting increase in solar radiation.

Fig 1: Spatial distribution of changes in NPP between 1982 and 1999.
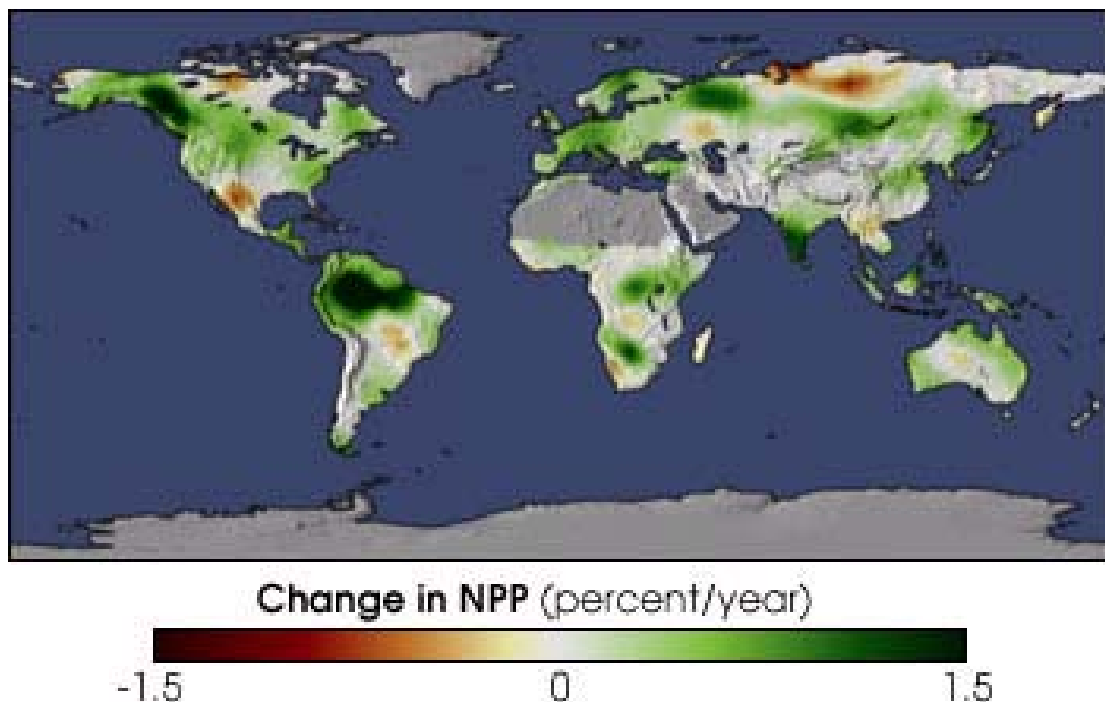
Mapping vapor pressure deficit:

Vapor pressure deficits (VPD) through their control over stomata regulate carbon and water exchanges. Currently spatial maps of VPD are generated by extrapolating observed data at a few points to the landscape. While this method is sufficient in data rich regions, large errors can result in regions where station density is low. We are testing a method for mapping VPD at 1km using land surface temperatures from MODIS. The logic behind this approach is that VPD above a surface is a reflection of the energy partitioning which is reflected in land surface temperatures. We tested this logic using MODIS LST and VPD observed at a number of flux tower sites around the continental U.S. A strong linear relation is observed between saturation vapor pressure at LST and daytime VPD, indicating the potential for mapping landscape level VPDs.

SVPd -- VPD (MODIS)

$y = -0.01 + 0.36x$
$r = 0.90$

Legend: CA_1, CA_2, CA_3, IL_1, MA_1, IN_1, MT_1, CO_1, CT_1, OR_1, WI_1, WI_2

Observed relation between MODIS based SVP and daytime VPD at flux tower sites.
Seasonal changes in VPD across the continental U.S derived from MODIS LST data are shown below. Our goal is to incorporate the spatial maps of VPD into our MOD 17 GPP/NPP algorithm, replacing the coarse resolution data from DAO.

Seasonal changes in VPD across the continental U.S. generated from MODIS LST.

VPD (81- 88 DOY, 2001)

VPD (225-232 DOY, 2001)
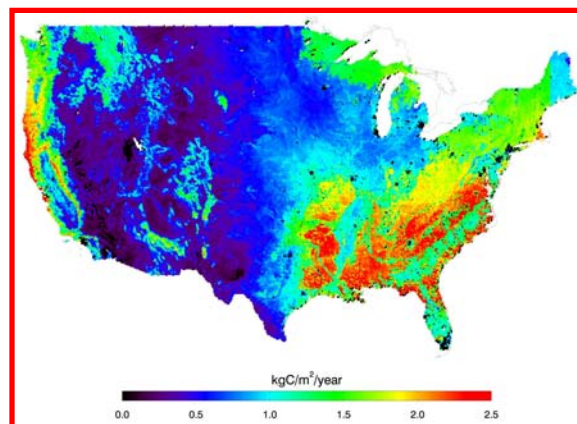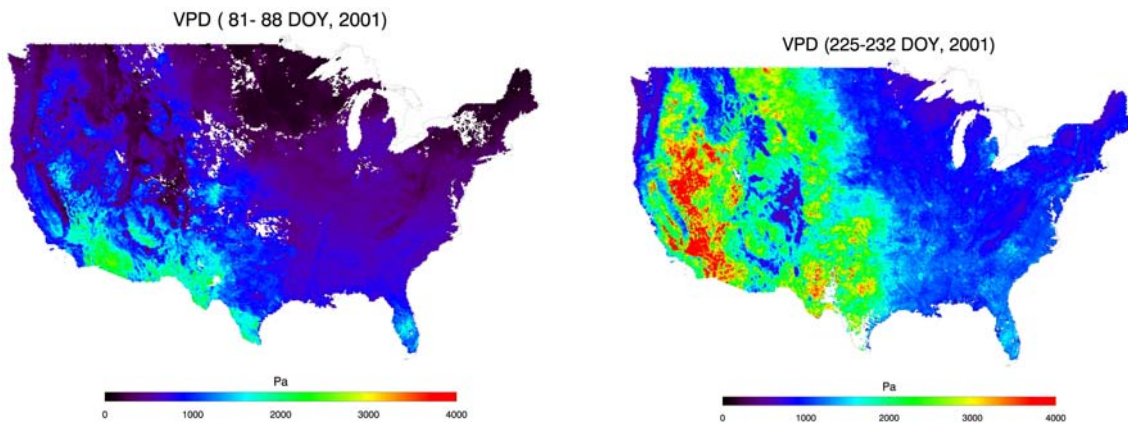
Gross primary production derived using VPD generated from MODIS LST.

MEETINGS ATTENDED

AGU FALL meeting, December 2003

PUBLICATIONS:

Nishida, K., R.R. **Nemani**, S.W. Running and J. Glassy. 2003. An Evapotranspiration Index from Aqua/MODIS for monitoring surface moisture status. *IEEE Transactions on Geoscience and Remote Sensing*, 41(2): 493-501.

Nishida, K., R.R. **Nemani,** S.W. Running and J. Glassy. 2003. Remote sensing of land surface evaporation: Theoretical basis for an operational algorithm. *Journal of Geophysical Research* VOL. 108, NO. D9, 4270, doi:10.1029/2002JD002062, 2003

Johnson, L., D. Roczen, S. Youkhana, R.R. **Nemani** and D.F. Bosch. 2003. Mapping vineyard leaf area with multispectral satellite imagery. Computers & Agriculture, 38(1): 37-48.

White, M.A., and R.R. Nemani. 2003. Canopy duration has little effect on annual carbon storage in the eastern United States broadleaf forest. Global Change Biology, 9(7), 967-1968.

Nemani, R.R., M.A. White, Lars Pierce, Petr Votava, Joseph Coughlan and S.W. Running. 2003. Biospheric monitoring and ecological forecasting, Earth Observation Magazine, 12 (2): 6-8.

Nemani, R.R., C.D. Keeling, H. Hashimoto, M. Jolly, R. Myneni, C.J. Tucker, S. Piper and S. Running. 2003. Climate driven increases in terrestrial net primary production from 1982 to 1999, Science 300, 1650 (2003).

ACTIVITIES OF M. Zhao (Postdoctoral Researcher)

1. Enhancement of MOD17 products

There are two main problems exist in MOD17 algorithm process. One is the mismatch in spatial resolution between coarse resolution meteorological data, DAO, and nominal 1km MODIS pixel. The other is cloudy contaminated MOD15A2 (8-day Fpar/Lai) input. To solve the first problem, a non-linearly spatial smooth was used to interpolate DAO data to 1km scale. This smooth not only eliminates unrealistic 'big' DAO cells imposed on MOD17 image, but also improves the accuracy of meteorological inputs (Fig.1, Fig.3). For the second problem, temporal linear filling unreliable MOD15 was employed to replace the cloudy contaminated MOD15A2 for a given MODIS pixel (Fig. 2). These methods improved MOD17 products greatly. We also tuned BPLUT for MOD17 because of the improvements of collection4 MOD15A2 and GEOS402 DAO data set. Based on this new BPLUT and above methods, enhanced MOD17 for 2001 and 2002 has been produced and released to the public (Fig. 4). We also compared MODIS NPP with Ecosystem Model-Data Intercomparison (EMDI) NPP data set, and the results show that MOD17 NPP are reliable (Fig. 5).
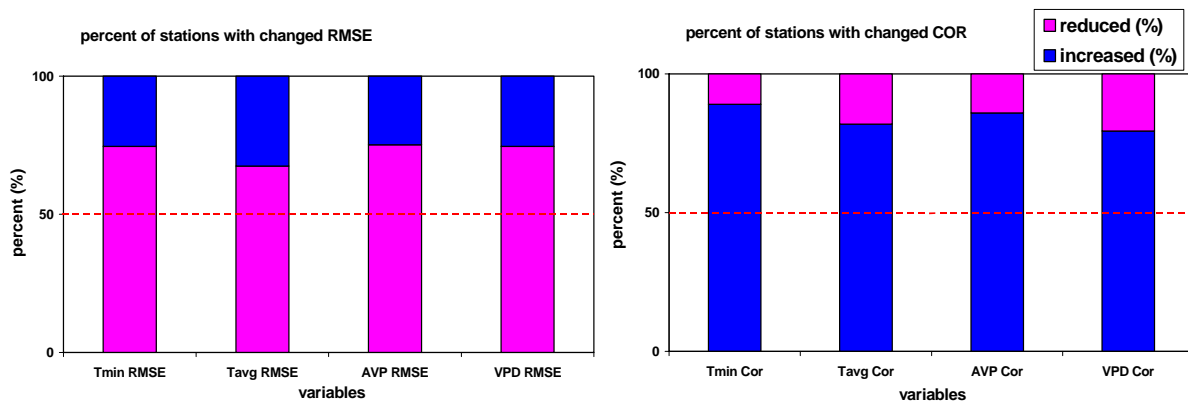

Fig. 1 Percent of WMO stations (n > 5000) with changes in RMSE and COR between spatially interpolated and non-interpolated DAO. For most stations, DAO accuracies are improved (reduced RMSE and increased COR) as a result of spatial interpolation.
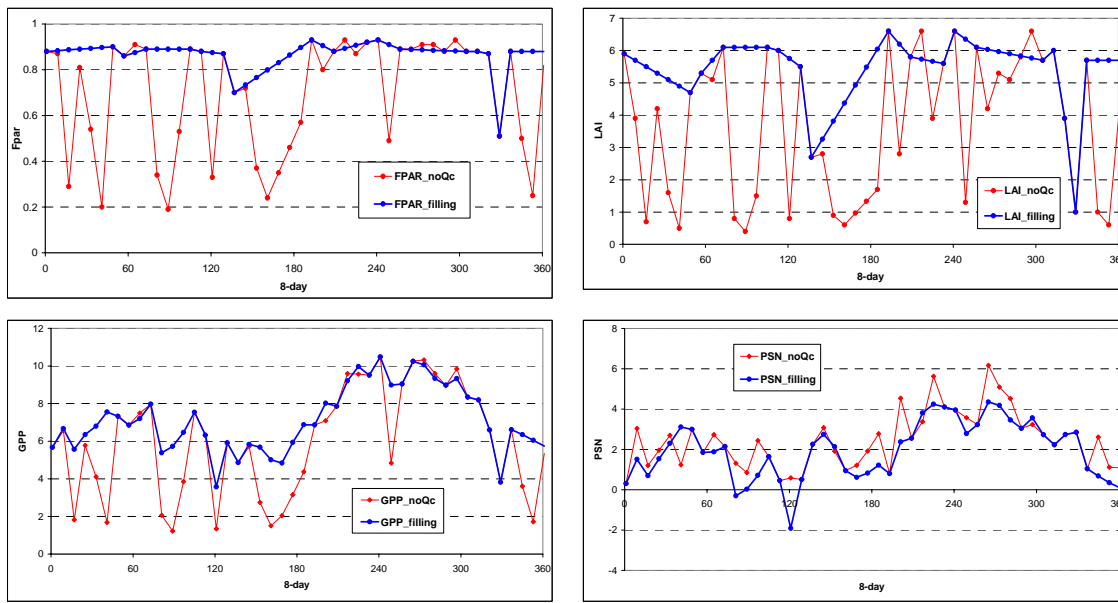
Fig. 2 Comparison of temporal profiles of 2001 Collection 4 MOD15A2 with original values (FPAR_noQc, LAI_noQc) and temporally linearly-filled FPAR and LAI (FPAR_filling, LAI_filling), and of temporal profiles of MOD17A2 with original MOD15A2 inputs (GPP_noQc, PSN_noQc), and MOD17A2 with filledMOD15A2 (GPP_filling, PSN_filling). The pixel is located in the Amazon rainforest (lat = -1.0, lon = -60) with the MODIS land cover Evergreen BroadleafForest (EBF).
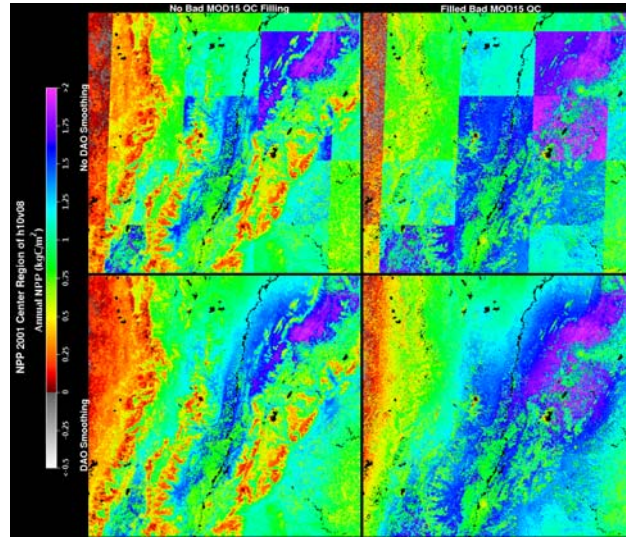

Fig. 3 One example of how spatial DAO interpolation/non-interpolation, and temporal filling/non-filling MOD15A2 influence MOD17. This tile (h10v08) is located near Amazon basin, and Evergreen Broadleaf Forest (EBF) is the dominant biome type
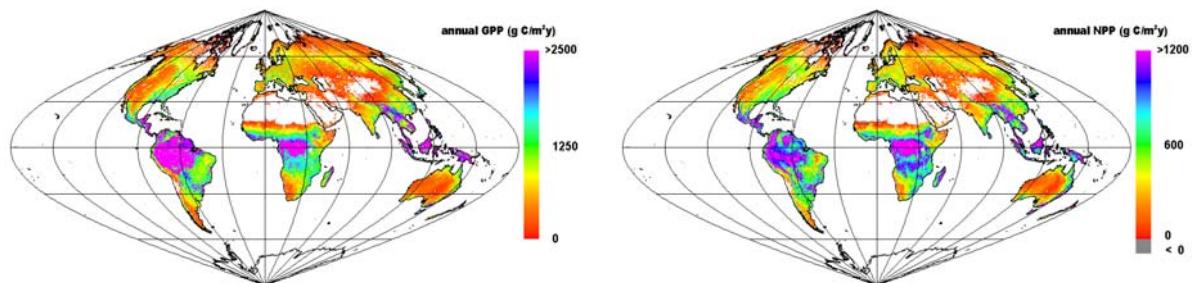
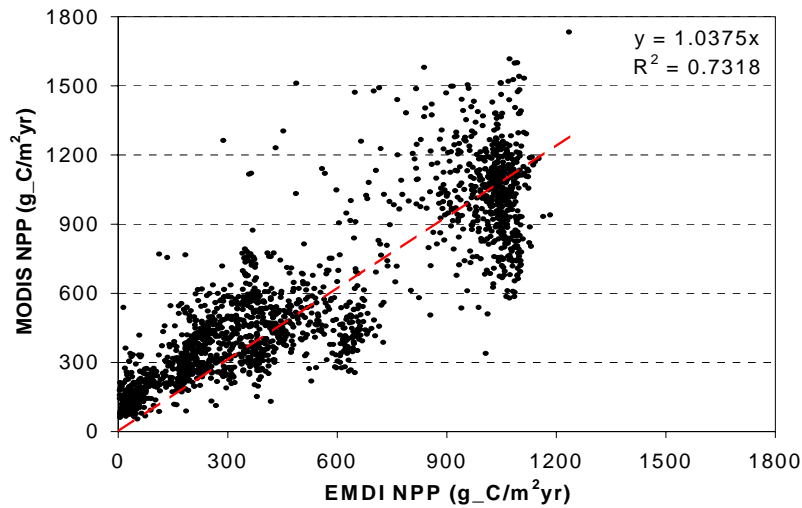**Fig.4 Annual GPP/NPP mean for 2001 and 2002 at the global scale.**

Fig.5 Validation of MODIS NPP with EMDI NPP data set.

2. Finished MOD17 source codes for 1km resolution meteorological data (SOGS) inputs.

This source code has been revised further by Matt Reeves for the wheat project in the lab.

3. Finished 250 meters MOD17 source codes.

This is important for natural resource management at local scale level.

4. Using MOD17 algorithm to study Pan-Arctic region NPP inter-annual variability and long-term trend based on AVHRR data set and RIMS-NCEP data set.

Documentation:

Heinsch F. A.,M. Reeves,P. Votava,S. Kang,C. Milesi,M. Zhao,J. Glassy,W. M. Jolly,R. Loehman,C. F. Bowker,J. S. Kimball,R. R. Nemani,S. W. Running. 2003. User's Guide GPP and NPP (MOD17A2/A3) Products NASA MODIS Land Algorithm.

Publications:

Kang, S., S.W. Running, J. Lim, *M. Zhao*, C. Park, R. Loehman. 2003. A MODIS-based climatological phenology model for detecting onset of growing seasons in temperate mixed forests in Korea.Remote Sensing of Environment, 86, 232-242.

Turner DP, Ritts WD, Cohen WB, Gower ST*, Zhao M*, Running SW, Wofsy SC, Urbanski S, Dunn A, Munger JW. 2003. Scaling gross primary production (GPP) over boreal and deciduous forest landscapes in support of MODIS GPP product validation. Remote Sensing of Environment, 88, 256–270.

Running S. W., R. R. Nemani1, F. A. Heinsch, M. *Zhao, M*. Reeves, M. Jolly, A continuous Satellite-derived measure of global terrestrial primary productivity: future science and applications. Bioscience (accepted)

Poster in AGU:

Zhao M., W. Running, R. R Nemani. Current status of MOD17 and what Influence its results.

ACTIVITIES OF Faith Ann Heinsch (Postdoctoral Researcher)

Summary:

It is important to determine the accuracy of the MOD17A2 (GPP) algorithm at the local scale as well as the global scale. Therefore, we are collaborating with AmeriFlux researchers at thirteen sites throughout the U.S. and Canada (http://public.ornl.gov/ameriflux/Participants/Sites/Map/index.cfm).

These sites cover a wide range of both climate and biome types. Researchers have provided us with eddy covariance flux tower-based gross primary production (GPP) estimates and meteorological data for 2001. Comparisons are then made with the 8-day and annual GPP calculated using an off-line version of the MODIS algorithm (Version 4.5) in combination with both Collection 4 MOD15A2 (LAI/FPAR) and DAO meteorological data (GEOS402). This version of the MOD17A2 algorithm contains a revised Biome-Properties Look-Up Table (BPLUT) that provides reasonable estimates of GPP at the global scale. When compared with annual tower GPP, the MOD17A2 algorithm, with the new BPLUT and tower meteorology, shows an improvement ($r^2 = 0.75$) over previous versions of the of model ($r^2 = 75$). Current analysis involves two forms of the DAO data: the standard output (1° x 1.25°) and a non-linearly interpolated output (1-km^2) developed at NTSG. Use of the standard DAO meteorology with the GPP algorithm indicates that the algorithm tends to overestimate GPP over a 7 x 7 km grid surrounding each tower site (Figure 1, $r^2 = 0.60$). While use of the interpolated DAO meteorology does not change the results at many towers ($r^2 = 0.60$), it can have a dramatic effect on towers which are located at the edge of DAO cells (Figure 2), particularly in estimates of vapor pressure deficit (VPD). Use of tower meteorology with the MOD17A2 algorithm provides a further improvement of the algorithm (Figure 3, $r^2 = 0.75$), indicating that much of the

error associated with the algorithm comes from the use of coarse resolution meteorological data. We hypothesize that this is larger due to discrepancies in the vapor pressure deficit (VPD).

Both versions of the DAO input data consistently underestimate actual VPD in drier regions, resulting in the overestimation of GPP in these areas. Additional error is associated with MOD15A2 LAI/FPAR inputs, primarily resulting from cloud contamination. This issue is been currently resolved by using the most rigorous quality control of the MOD15A2 data, and filling missing periods via linear interpolation. Unfortunately, in cloudy areas, these missing periods can be substantial. Future work includes the addition of more sites and more years of data to the comparison. The sensitivity of the algorithm to the seasonality of the MOD15A2 will also be explored, particularly for evergreen sites.

Figure 1. Comparison of MODIS GPP estimates from the MOD17A2 algorithm with flux tower estimates of GPP using the official MOD15A2 (Collection 4) and DAO (GEOS402) inputs.
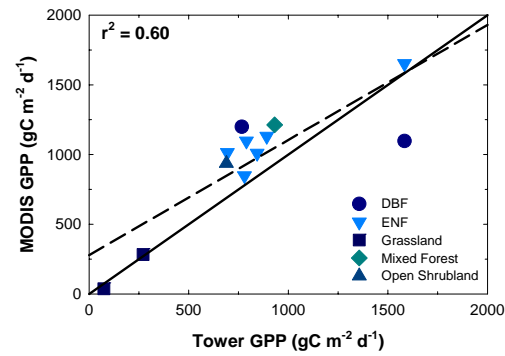

Figure 2. The effects of using a non-linearly interpolated computation of the DAO meteorological data at the Sky Oaks, CA site.
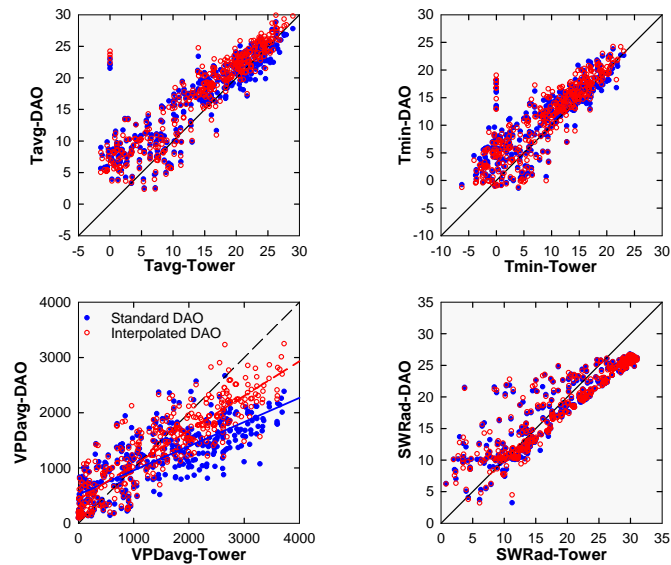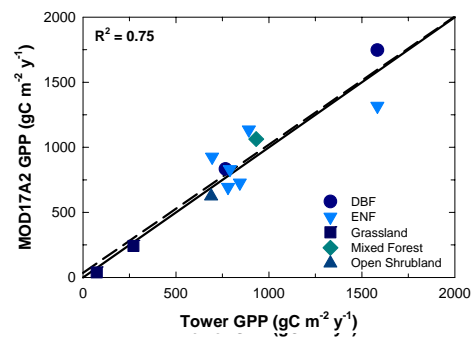

Figure 3. Comparison of MODIS GPP estimates from the MOD17A2 algorithm using tower meteorology as an input.

Conference Presentations:

ChEAS Annual Meeting, Minoqua, WI   29 June – 2 July 2003
  Heinsch, FA. "Use of Biome-BGC with the ChEAS flux tower network to
    address scaling issues"

FluxNet Mini Workshop, Tahoe City, CA   11 – 14 August 2003
  Heinsch, FA and SW Running. "MODIS GPP, NPP and LAI: What is being
    done?"

AmeriFlux Science Meeting, Boulder, CO   14 – 16 October 2003
  Heinsch, FA, M Zhao, SW Running, and JS Kimball. "Modification and
    Validation of the MODIS GPP and NPP (MOD17A2/A3) Products"

AGU Fall Meeting, San Francisco, CA   8 – 12 December 2003
  Heinsch, FA, JS Kimball, M Zhao, and SW Running. "Validation of the MODIS
    GPP Algorithm (MOD17A2) Using Eddy Flux Tower Data"

ACTIVITIES OF Sinkyu Kang (Postdoctoral Researcher)

Detecting phonological changes from MODIS Leaf Area Index product

A regional phenology model for detecting onset of vegetation greenness was developed using year 2001MODIS land products in temperate mixed forests in Korea. The model incorporates a digital elevation model (DEM), Moderate Resolution Imaging Spectroradiometer (MODIS) Landcover and Leaf Area Index (LAI) products, and climate data from weather monitoring stations. MODIS-based onset of greenness varied spatially and showed significant correlation with air temperature ($r = -0.70$, $p<0.001$). Our modeling methodology is to relate thermal summation calculated using the MODIS-based timing of onset with 30-year mean air temperature. Onset of greenness is expected to occur at values above the critical thermal summation threshold, and is predicted to vary spatially. An algorithm for downscaling eight-day composite MODIS LAI product to a daily unit was introduced and its predictability was validated using ground-measured onset of greenness. Two unknown parameters and the best regression were determined by iterative cross-validation. Minimal cross-validation errors between the predicted and MODIS-based timings of onset were found at a mean absolute error (3.0 days) and bias (+1.6 days). The predicted onsets show good agreement with ground-measured onset of greenness (MAE = 2.5 and bias = +2.5 days). This study demonstrates the utility of MODIS Land products as tools for detecting spatial variability in phenology across climate gradients.

Publications

Sinkyu Kang, Steve W. Running, Jong-Hwan Lim, Maosheng Zhao, Chandra Park, Rachel Loemann (2003) A Regional Phenology Model for Detecting Onset of Greenness in Temperate Mixed Forests, Korea: An Application of MODIS Leaf Area Index (LAI). Remote Sensing of Environment, 86, 232-242.

Kang, S., D. Lee, J.S. Kimball. (2003) The effects of spatial aggregation of complex topography on hydro-ecological process simulations within a rugged forest landscape: Development and application of a satellite-based topoclimatic model. Canadian Journal of Forest Research (in press).

Kang, S., Steve W. Running, Maosheng Zhao, John S. Kimball, Joeseph Glassy (2003). Improving continuity of MODIS terrestrial photosynthesis products using an interpolation scheme for cloudy pixels. International Journal of Remote Sensing (in review).

Kang, S., D. Lee, J. Lee, S.W. Running. Topographic and Climatic Controls of Forest Hydro-Ecological Processes in a Rugged Temperate Hardwood Forest in Korea. Agricultural and Forest Meteorology (in review).

Kang, S., J.S. Kimball, S.W. Running. Simulating effects of fire disturbance and climate change on regional forest productivity and evapotranspiration in boreal ecosystems. Global Change Biology (in review).

Presentations

1. Sinkyu Kang and NTSG members. Monitoring local and global vegetation productivity using Moderate Imaging Spectrometer (MODIS). A paper presented at the 88th ESA Meeting held in Savannah, GA in August 3-8, 2003.
2. Sinkyu Kang, John S. Kimball, Faith Ann Heinsch, Maosheng Zhao, Steve W. Running. Monitoring and predicting terrestrial hydro-ecological processes using MODIS and BIOME-BGC, and its application to arctic ecosystems. An invited lecture given in IARC, Fairbanks, AL in August 11-18, 2003.
3. Sinkyu Kang and NTSG members. Integration of remote sensing and ecosystem modeling for monitoring terrestrial hydrologic and biospheric variables. An invited lecture given in Kangwon National University, Chunchon, Korea in October 9, 2003.
4. Sinkyu Kang and NTSG members. Monitoring terrestrial hydrologic and biospheric variables in rugged forested landscapes: application of remote sensing and ecosystem modeling. SNU-Hokkaido University Joint Symposium held in Seoul, Korea in October 17-18, 2003

Meetings attended

The 88th ESA Meeting held in Savannah, GA in August 3-8, 2003.

ACTIVITIES OF Qiaozhen MU (Postdoctoral Researcher)

1) I have written a C program to retrieve the 250-m LAI and FPAR from 250-m MOD13Q1 NDVI based on the MOD15A1 backup algorithm from Boston University.

2) I modified Maosheng's cutout C programs for the towers for MOD12Q1, MOD15A2, MOD17A2 and MOD17A3, which can mosaic different tiles if the cutout is out of one tile.

3) I have used MT-CLIM43 to deal with daily meteorology climate data for 190 stations over China (10 years from 1989 to 1998) to get the daily data sets for Biome-BGC4.1.1 inputs. I ran the point Biome-BGC4.1.1 for several stations. And I have modified the point Biome-BGC4.1.1 to spatial Biome-BGC4.1.1. The distributions of the 190 China meteorology stations and the MODIS land cover over China are shown in figure 1.
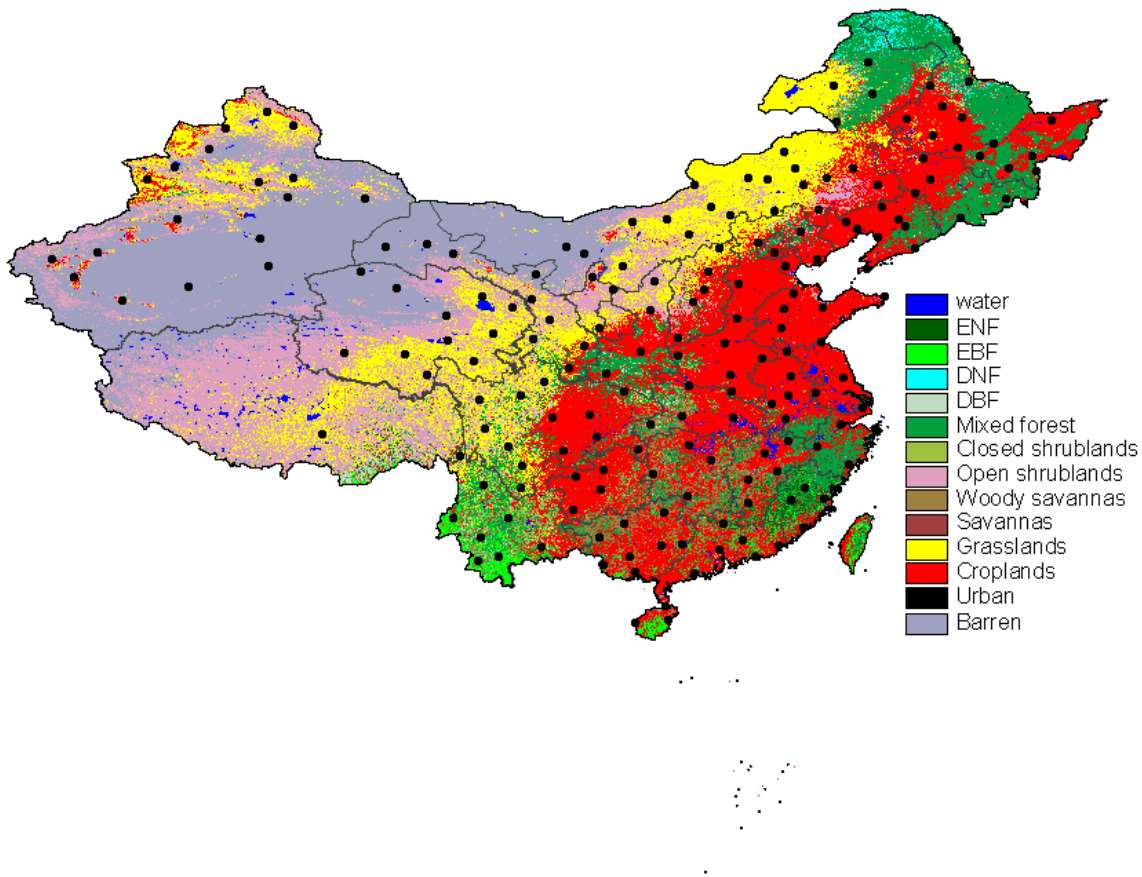
Fig. 1. The distributions of the 190 China meteorology stations, the MODIS land cover over China

ACTIVITIES OF Matt Jolly (Ph.D. Student)

Surface Observations Gridding System (SOGS)

SOGS is designed to retrieve, store and interpolate surfaces of meteorological data over any spatial scale that the point data are available. This year we continued the development of the system by adding the near realtime retrieval of point data sources to allow the system to interpolate these data sources operationally and provide the results to the scientific community as quickly as possible.

Briefly, we retrieve and store meteorological data in an SQL database, interpolate those data using a variety of mathematical techniques and display the results over multiple spatial extents. We interpolate surfaces data using a modular prediction logic. Using modular prediction logics allows the system to scale to easily implement new predictor as methods improve. We tested the system by implementing three different mathematical processors that interpolate meteorological point-source data: ordinary kriging, a truncated Gaussian filter, and inverse distance weighting and found that each of the methods performed well.

Publications:

William M. Jolly, Jonathan M. Graham, Andrew Michaelis, Ramakrishna Nemani, and Steven W. Running.   A flexible, integrated system for generating meteorological surfaces derived from point sources across multiple geographic scales. Environmental Modeling and Software. In Review.
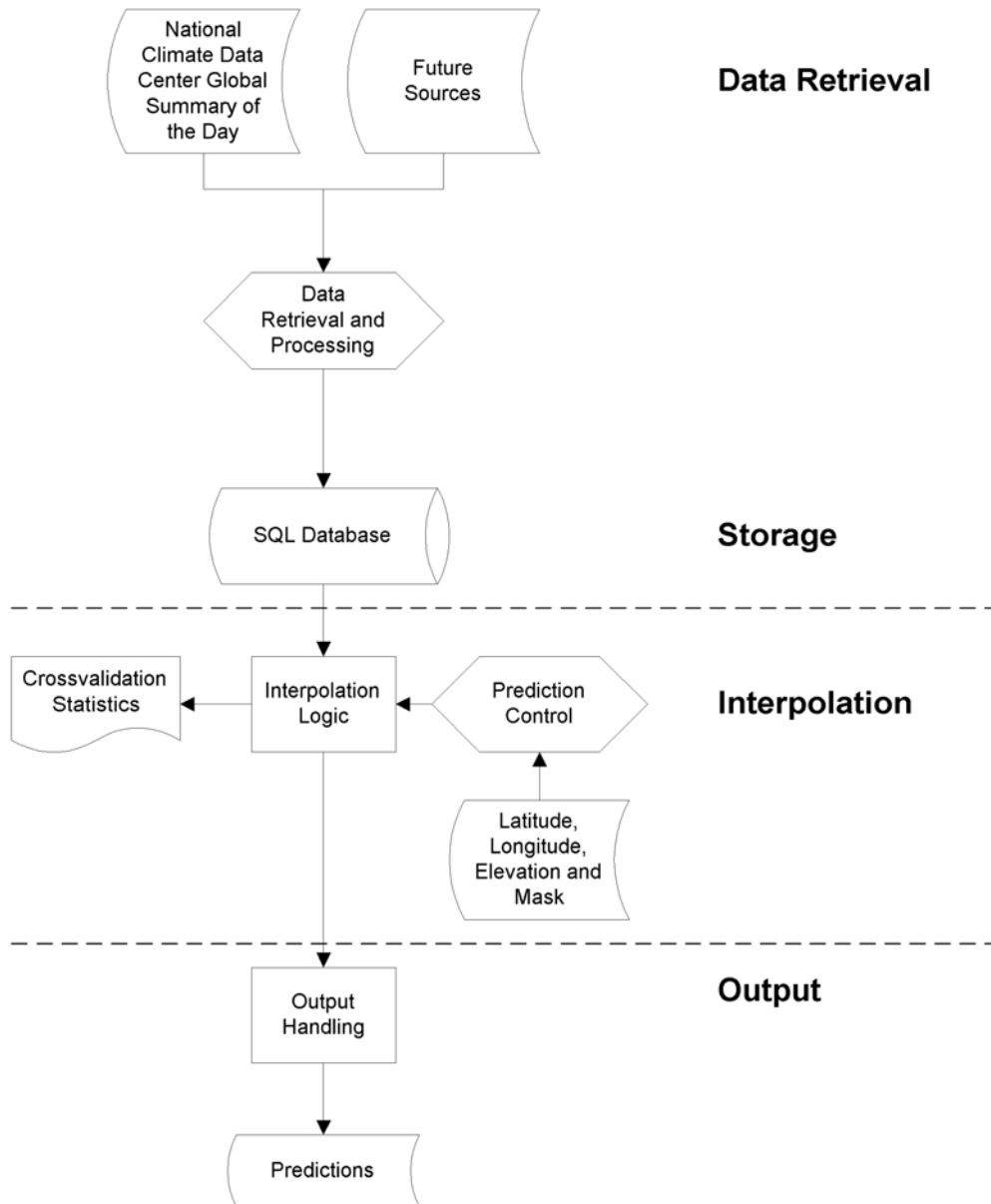
Figure 1- Flow diagram of the Surface Observations Gridding System (SOGS). Three main components that comprise the system are: data retrieval and storage, interpolation and output handling. Data retrieval is configured to automatically retrieve the most recent data available and insert those data into the SQL database. Interpolation methods are modular and allow maximum flexibility in implementing new routines as they become available. Outputs are generated on the prediction grid that is determined by the latitude, longitude, elevation and mask layers.
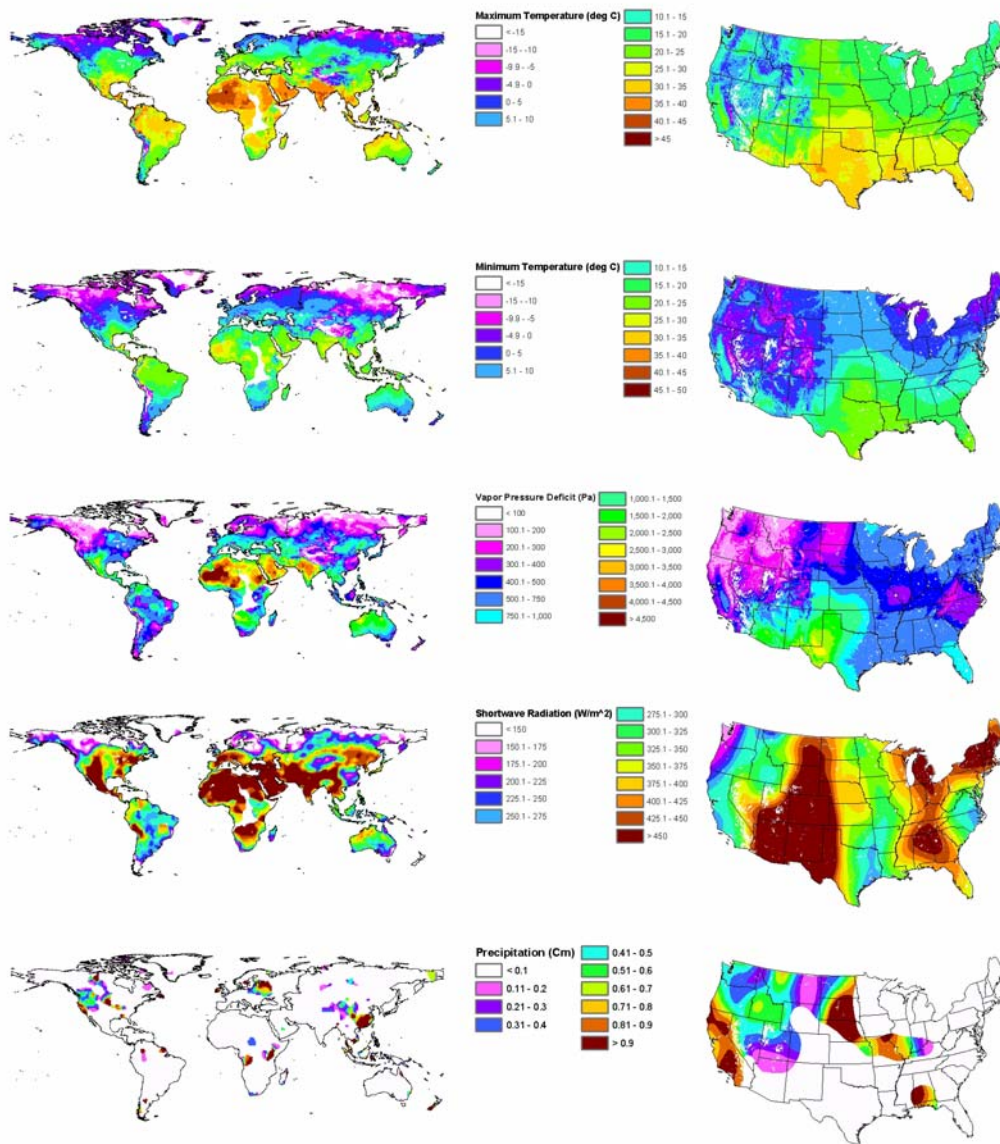
Figure 2 - Example of two different spatial resolution tests for all five variables for May 4th, 2003 using NCDC Global Surface Summary of the Day data. For this test, data were interpolated using the truncated Gaussian filter.

ACTI VITIES OF M. Reeves (Ph.D. Student)

Activities of the last six months include manuscript preparation and teaching another MODIS workshop. I have been working on three manuscripts. The first, entitled "Usefulness and limits of MODIS GPP estimates for predicting wheat yield" summarizes a years worth of research on using MODIS gross and net primary productivity estimates for estimating wheat yield in Montana and North Dakota. This was submitted to the International Journal of Remote Sensing on 5 June, 2003.   MODIS GPP estimates can reliably be used as a tool for estimating state level wheat yields. However, the standard MODIS GPP estimates should not be used in conjunction with MODIS landcover for estimating county or climate district level wheat yield (Fig 1).
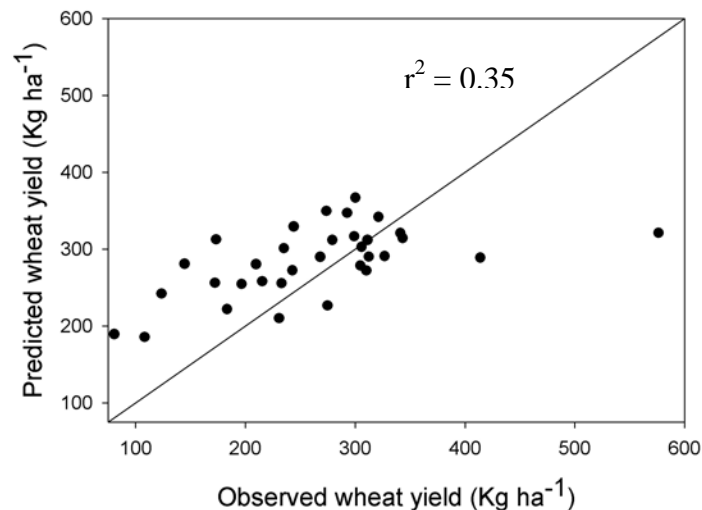

Fig 1.   Relationship between predicted and observed wheat yield for counties of Montana with greater than 12,000 ha of planted wheat in 2001.

This is because MODIS land cover does not differentiate crop types and therefore adds significant noise to the analysis. MODIS GPP estimates can and should be used in a wheat yield algorithm that partitions carbon to grain based on phenological stage, especially with the aid of a

more crop specific analysis mask. The second manuscript entitled "Combining meteorological and MODIS productivity data with knowledge of farming practices for improved estimates of wheat yield". This paper expands on the first to overcome the stated limitations. These improvements include a user defined mask of dryland agriculture for the area of interest, a phenomenologically oriented growth stage program, and a grain yield subroutine that relies on growth stage, temperature, and drought stress to allocate sequestered carbon to grain. These changes greatly improve our ability to predict wheat yield using MODIS GPP (Figure 2).
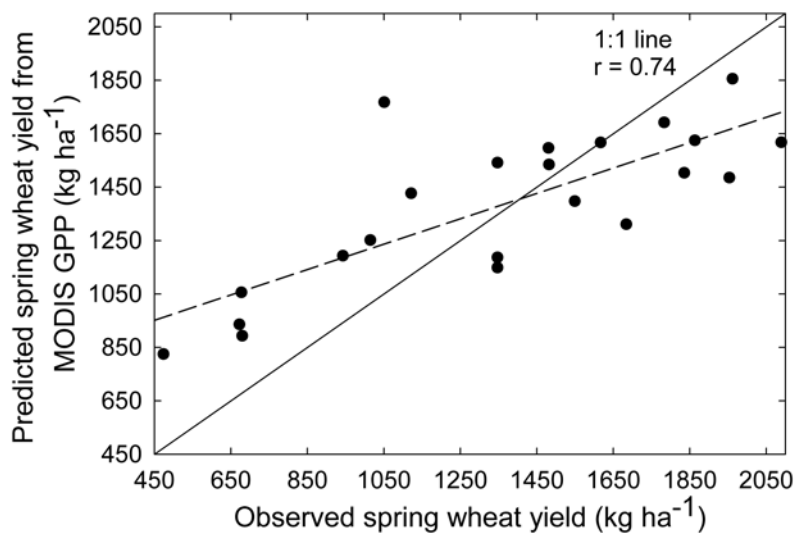

Figure 2. Comparing predicted and observed spring wheat yield for selected counties in Montana. The best-fit linear relationship is y = 0.4748x + 737.92 (r = 0.78). Each dot represents a county in Montana with > 12,000 ha of reported dryland-farmed spring wheat in 2001.

The third paper is entitled "Comparing Scaled Rangeland Biomass Measurements to Improved Estimates of MODIS Primary Productivity". The major thrust of this paper is to demonstrate the usefulness of MODIS productivity estimates for monitoring rangeland vegetation dynamics, particularly in response to moisture stress. MODIS PSNnet is strongly

related to above – ground green biomass during peak greenness, especially during favorable
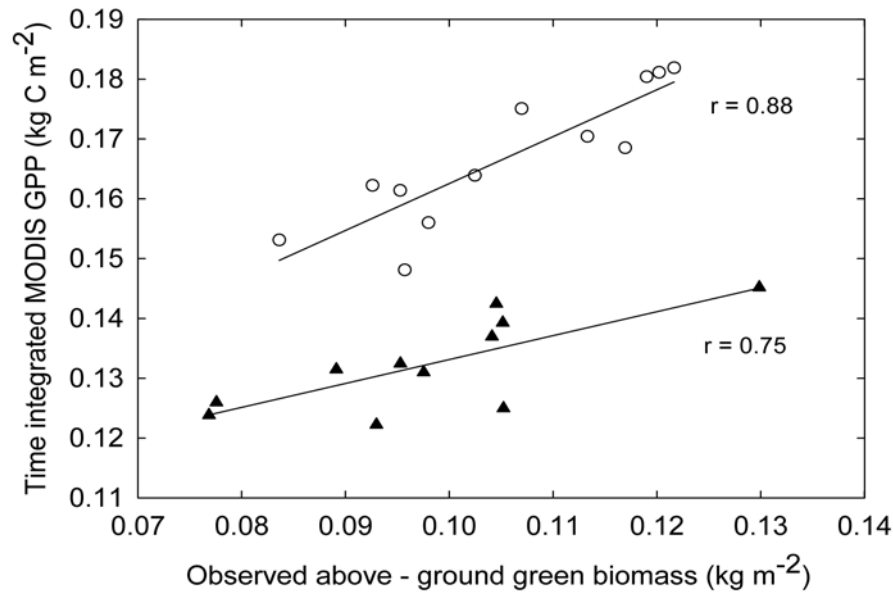years.

Figure 3. The relationship between scaled above - ground green biomass and MODIS derived GPP estimates integrated from composite period 1 through composite period 193 (kg C m^{-2}) for 2001(○) and 2002 (▲).

MODIS Workshops

I was a co - instructor at a MODIS workshop in Wageningen, The Netherlands on 11
December, 2003 . This workshop focused on primarily interpreting MODIS land products,
though there was some emphasis on practical applications for MODIS productivity estimates.

Activities of Cristina Milesi (PhD candidate) – Year 2003

Global human population and net primary productivity

As the capabilities for monitoring global NPP (Net Primary Productivity) are improving, we need to start incorporating a spatially explicit human dimension in the analysis of the biophysical changes Earth is undergoing. This effort may help understanding the relevance of these changes in terms of global habitability. I used recently available satellite-based NPP estimates, along with gridded population at 0.5 resolution, first to identify the global distribution of human population with reference to NPP and to the various climatic constraints (temperature, water and cloud cover) that limit NPP, second to analyze recent trends in global NPP in relation to population trends, and third to identify populations that are vulnerable to changes in NPP due to interannual variability in climate. Over half of the global human population is presently living in areas with above the average NPP of 490 g C m^{-2} year^{-1}. By 1998, nearly 56% of global population lives in regions where water availability strongly influences NPP. Per capita NPP declined over much of Africa between 1982 and 1998, in spite of the estimated increases in NPP (Figure 1 and Figure 2). On average, the NPP over 40% of the total vegetated land surface has shown significant correlations with ENSO-induced climate variability affecting over 2.8 billion people. Recent availability of 1km NPP and population datasets will vastly improve our ability to monitor and respond to changes in habitability that require concerted efforts.
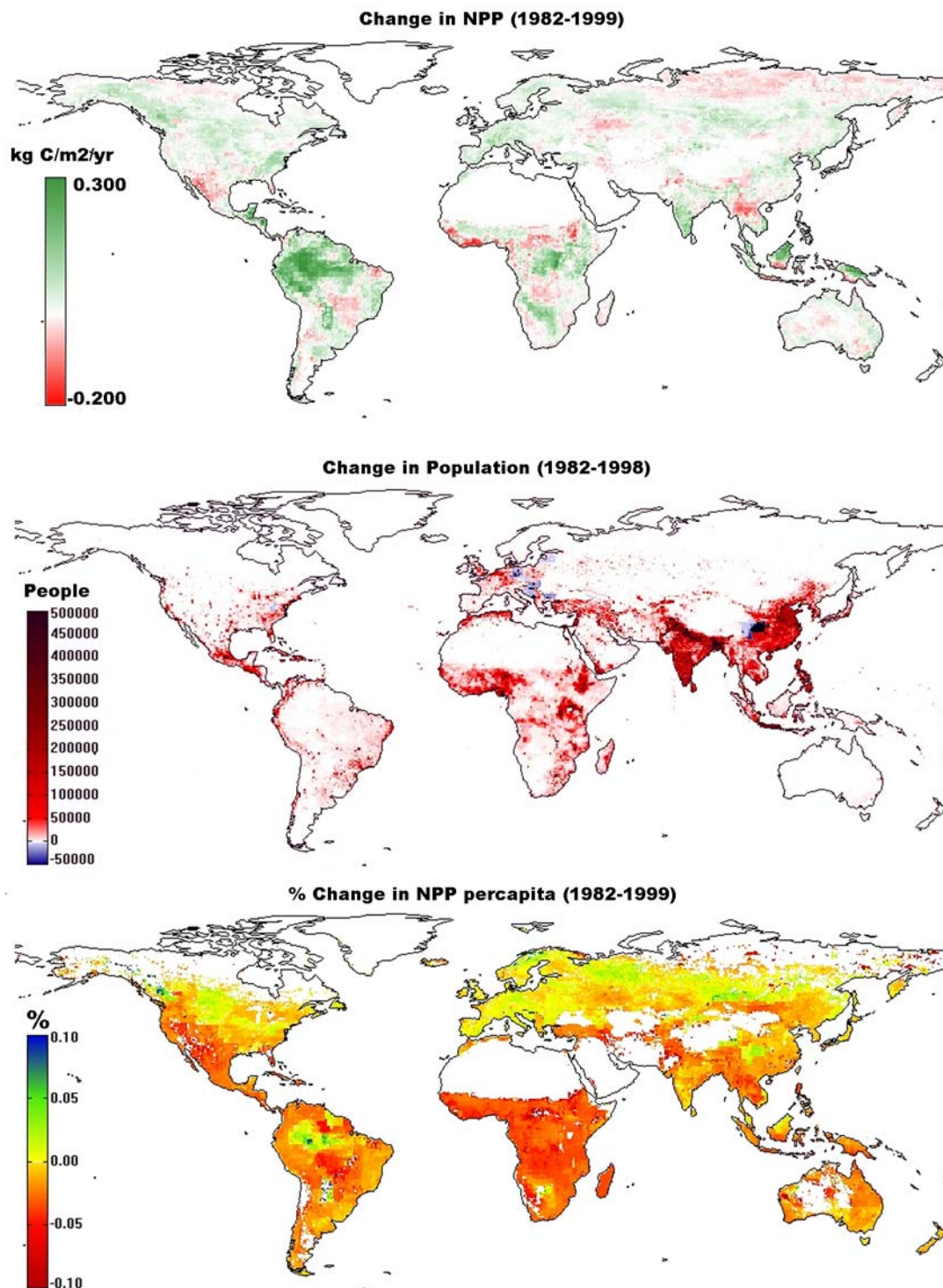
Figure 1. Spatial distribution of the changes in total NPP, population and per capita NPP observed during the period 1982-1999. While trends in NPP have been positive for most of the land areas, NPP per capita has decreased over 80% of the land areas. The most widespread decreases in NPP/per capita have been observed in the sub-Saharan Africa, in particular where marked population growth has been accompanied by decreases in NPP over the 1982-1999 period.
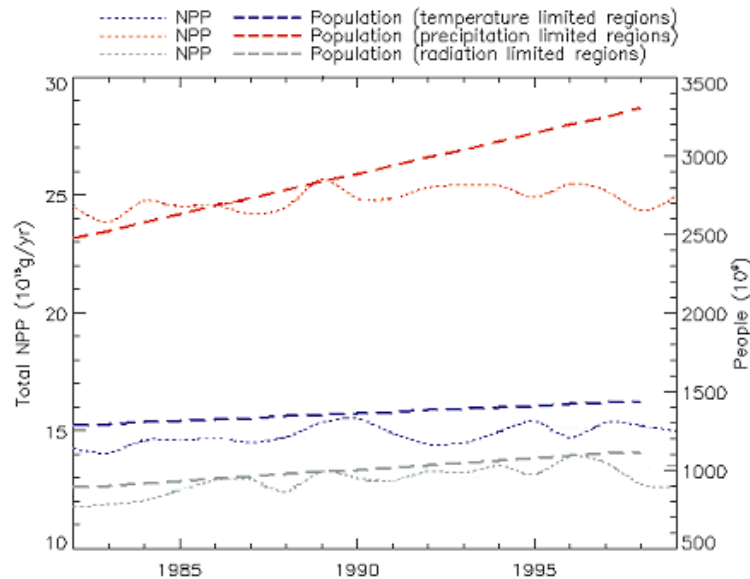
Figure 2. Times series of population (dashed line) and NPP (dotted line) for the period 1982-1999 by climatic constraints on NPP. In the temperate and tropical regions, the increasing trends in NPP have kept pace with the growth in human population. The rapid increase in population in the subtropical regions, on the other hand, has largely surpassed the overall modest increase in NPP, indicating the presence of higher human vulnerability to changes in local ecosystem functioning.

Synergistic use of MODIS and DMSP/OLS data to study the climatic effects of urbanization

As urban areas are continuing to expand globally, there is an increasing need for exploring methods for monitoring the environmental effects of urbanization. I explored the synergistic use of the fractional Impervious Surface Area (ISA), a measure of urban development density estimated from the Defense Meteorological Satellite Program/Operational Linear Scanner (DMSP/OLS), and the normalized difference vegetation index (NDVI), a surrogate for vegetation biomass, and the land surface temperature (LST) data from MODIS to understand how land cover changes due to urbanization influence the local climate. The analysis was performed over the metropolitan areas of Chicago, Atlanta and Phoenix, U.S.A. (Figure 3), representing different climatic regimes and urban development densities. The results (Figure 4) indicate that NDVI, which has been used to estimate fractional impervious areas in previous

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studies, does not necessarily decrease linearly as the fractional ISA increases, and may

eventually increase with the density of development due to vegetation management practices, as

in the case of Phoenix. In contrast, the nighttime LST consistently increases with the fractional

ISA in the three urban environments. The urban-rural differences in nighttime LST for the three

metropolitan areas are similar for equal values of imperviousness, indicating that the fractional

ISA from the DMSP/OLS and standard products from MODIS could provide a continental

physically based characterization of the surface that could be used to track the effects of
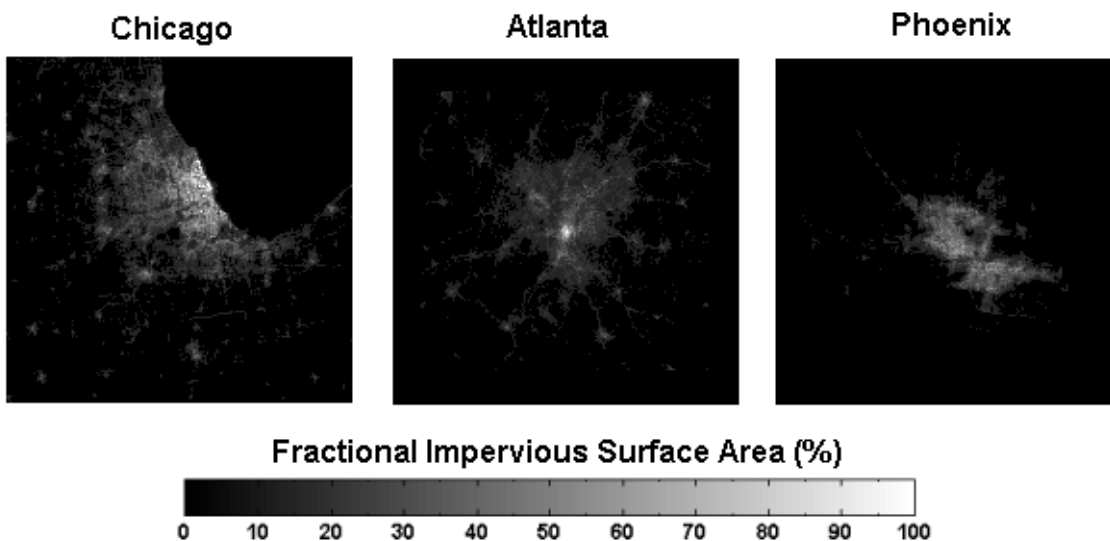
urbanization on the local and regional climate.

Figure 3. Fractional ISA for the metropolitan areas of Chicago, Atlanta and Phoenix.
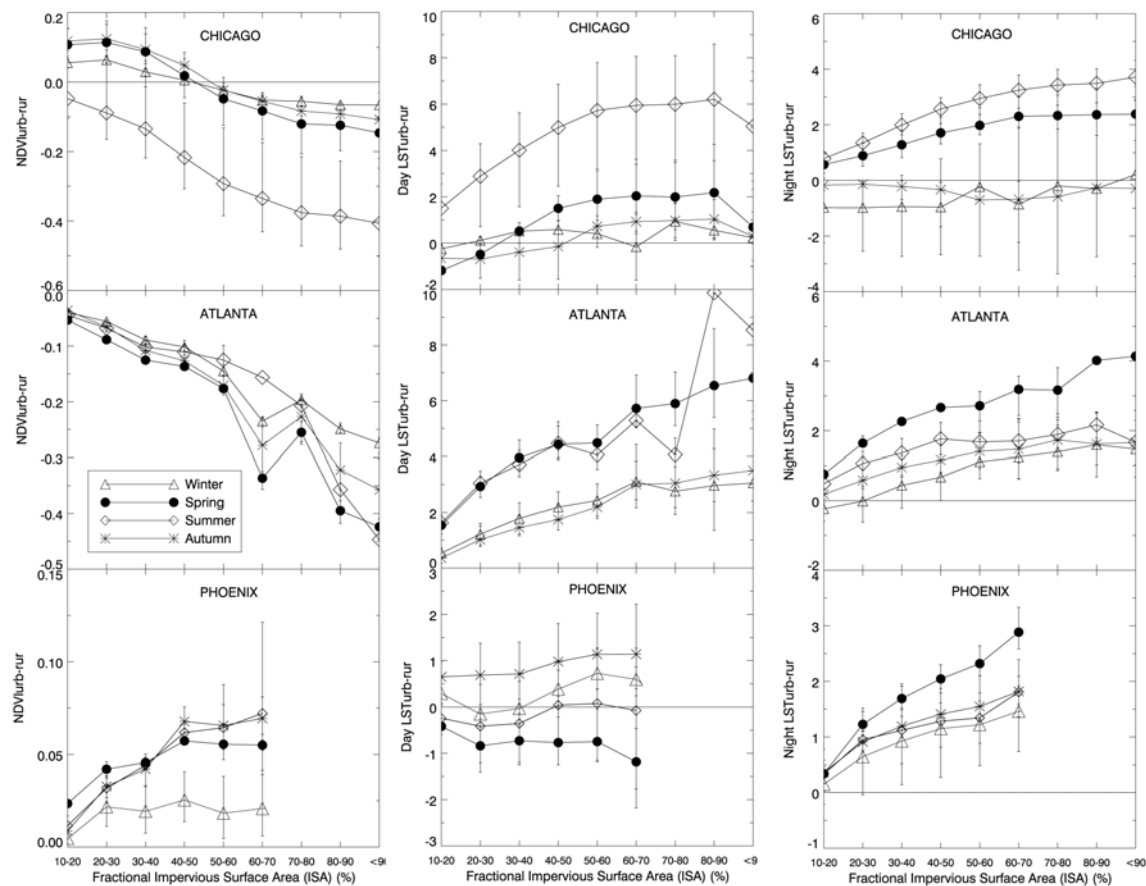
Figure 4. Urban-rural differences of NDVI (NDVIurb-rur), daytime LST (Day LTSurb-rur) and nighttime LST (Night LSTurb-rur) by fraction of impervious surface area for the metropolitan areas of Chicago, Atlanta and Phoenix.

Publications

C.D. Elvidge, <u>C.Milesi</u>, J.B. Dietz, B.T. Tuttle, P.C. Sutton, R.R. Nemani, J.E. Vogelmann (2004). U.S. Constructed Area Approaches the Size of Ohio. *EOS*. (Accepted)

C. Milesi, C.D. Elvidge, J.B. Dietz, B.T. Tuttle, R.R. Nemani, S.W. Running (2004). Synergistic use of MODIS and nighttime DMSP/OLS data for the assessment of the climatic effects of urbanization. *Remote Sensing of Environment* (Submitted).

Meetings

C. Milesi, H. Hashimoto, R. Nemani, S.W. Running *Assessing The Populations at Risk of Variability in Vegetation Productivity* (Poster). 2003 EGS-AGU-EUG Joint Assembly 06 - 11 April 2003, Nice, France

C. Milesi, H. Hashimoto, R. Nemani, S.W. Running. *Climate Variability, Vegetation Productivity and People at Risk*. START International Young Scientists Global Change Conference, 16 – 20 November 2003, Trieste, Italy

C. Milesi, C.D. Elvidge, R.R. Nemani, S.W. Running. *Synergistic use of MODIS and Nighttime DMSP/OLS Data for the Assessment of the Climatic Effects of Urbanization* (Poster). AGU Fall Meeting, San Francisco, CA, USA, 8 - 12 December 2003, San Francisco, CA

Activities of Rachel Loehman (PhD candidate)

Forecast Model for Hantavirus Pulmonary Syndrome

This research explores the utility of MODIS land products as epidemiological risk indicators for hantavirus pulmonary syndrome (HPS). In this context remotely sensed data are used as predictors of vector population dynamics. The scientific basis for the resulting forecast model is a trophic cascade hypothesis, which attributes growth of rodent populations to successive increases in food resources from one lower level of a food web to the next (Parmenter et al. 1999), as well as relationships between pathogens, hosts, and the environment that may be useful in predicting future outbreaks of HPS. Thus far no successful predictive model for HPS has been developed, and as noted by Mills et al., "When the environmental variables associated with increasing reservoir population densities are identified and quantified, a key component of a predictive model of human risk will be in place" (Mills et al. 1999)

A critical and unique feature of this model is the incorporation of the MOD17A2 data product, gross primary vegetation productivity (GPP), as a predictor of rodent density. In addition the MOD13 Vegetation Indices (VI) may be used to predict increased density of vector populations. Research efforts in the past year have focused on acquiring MODIS GPP data, including both the standard product and one derived using site-specific meteorology (Figure 1), and correlating GPP and meteorological data with minimum-number -alive (MNA) rodent population data from trapping sites supported by the Centers for Disease Control and Prevention (CDC) (Figure 2).
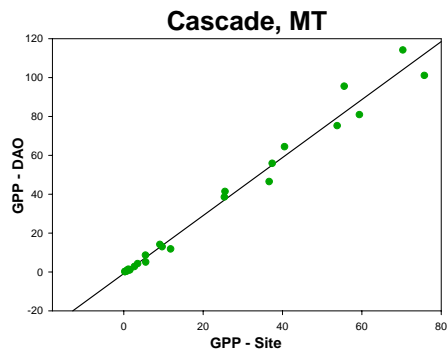
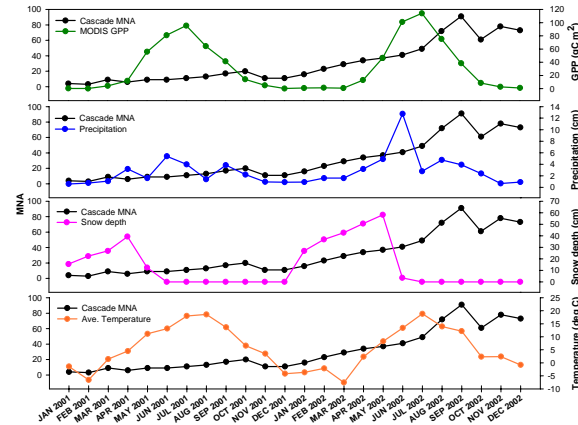Fig.1. MODIS Site-specific vs. DAO GPP

Fig.2. Cascade, MT GPP, Meteorology, and MNA

Because MODIS GPP is only available at the principal study site for 2001 through the current processing period, coarse-scale GPP data from the Advanced Very High Resolution Radiometer were obtained and compared with rodent data, to establish long-term relationships between variables. Annual sum GPP from AVHRR for 1994-2000 tracks very closely with vector population MNA for a large portion of the analytical period (Figures 3 and 4), suggesting that GPP may be a very powerful predictor of rodent population dynamics.
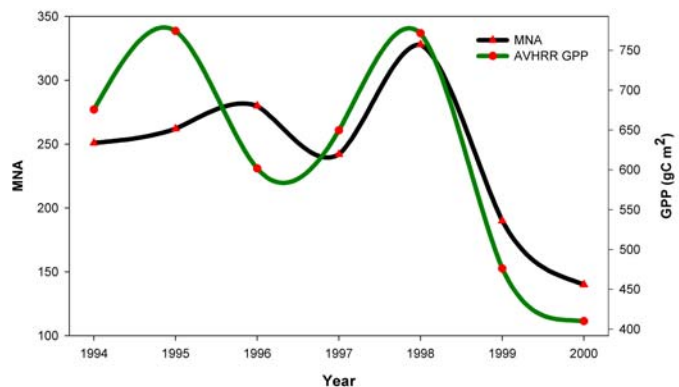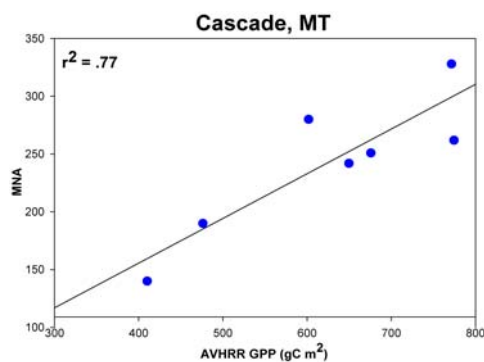
Figs.3,4. Cascade, MT MNA-GPP (AVHRR)

Work in the coming year will focus on expanding understanding of inter-annual and intra-annual relationships between hantavirus vector populations and antecedent meteorological and ecological parameters, measured by remote instruments. Both MOD17A2 and MOD13A2 products will be used extensively in these analyses.

Current research was presented at the Fall meeting of the American Geophysical Union as <u>Application of MODIS GPP to Forecast Risk of Hantavirus Pulmonary Syndrome Based on Fluctuations in Reservoir Populations</u> by Rachel Loehman, Faith Ann Heinsch, James N. Mills, Kent Wagoner, and Steve Running·

References

Mills, J. N., T. L. Yates, T. G. Ksiazek, C. J. Peters, and J. E. Childs. 1999. Long-term studies of hantavirus reservoir populations in the southwestern United States: rationale, potential, and methods. Emerging Infectious Diseases **5**:95-101.

Parmenter, C. A., T. L. Yates, R. R. Parmenter, and J. L. Dunnum. 1999. Statistical sensitivity for detection of spatial and temporal patterns in rodent population density. Emerging Infectious Diseases **5**:118-125.
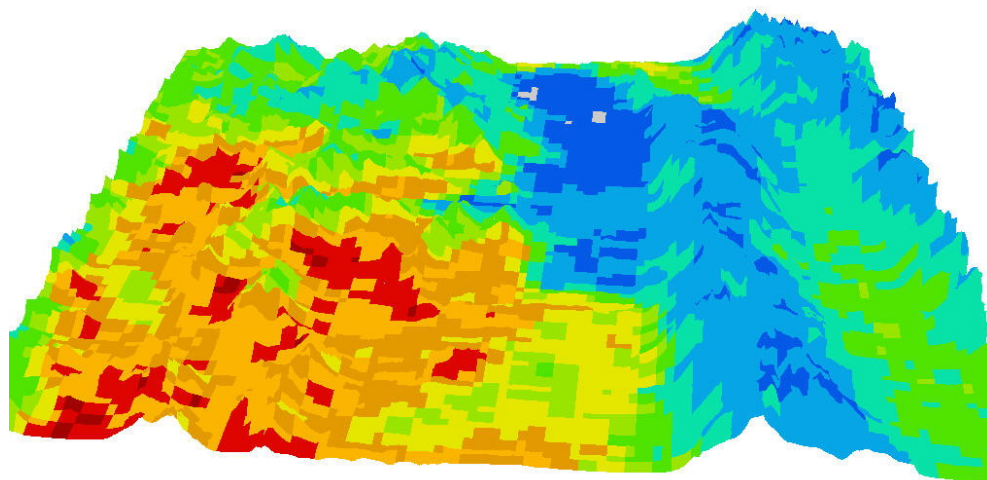
Activities of Matt Jones (Masters Student)

Visual Comparison of MODIS Land Surface Temperature Data to ASTER Land Surface Temperature Data

In an attempt to enhance the accuracy of current NTSG MODIS products, new methods are being tested for deriving the preliminary datasets that are used in current algorithms. This specific case involves the creation of a Vapor Pressure Deficit Map derived from MODIS Land Surface Temperature (LST) data, as opposed to the current algorithm that relies on DAO interpolated Land Surface Temperature. Since the MODIS LST data to be incorporated will be an 8-day composite, a first test was proposed to compare this data with a temporally correlated ASTER LST. Each dataset was draped over a DEM to allow for a visual comparison of temperature values and to assess the accuracy of the 8-day image. From the initial comparison, the MODIS LST provided an accuracy level high enough to encourage further research on this topic.
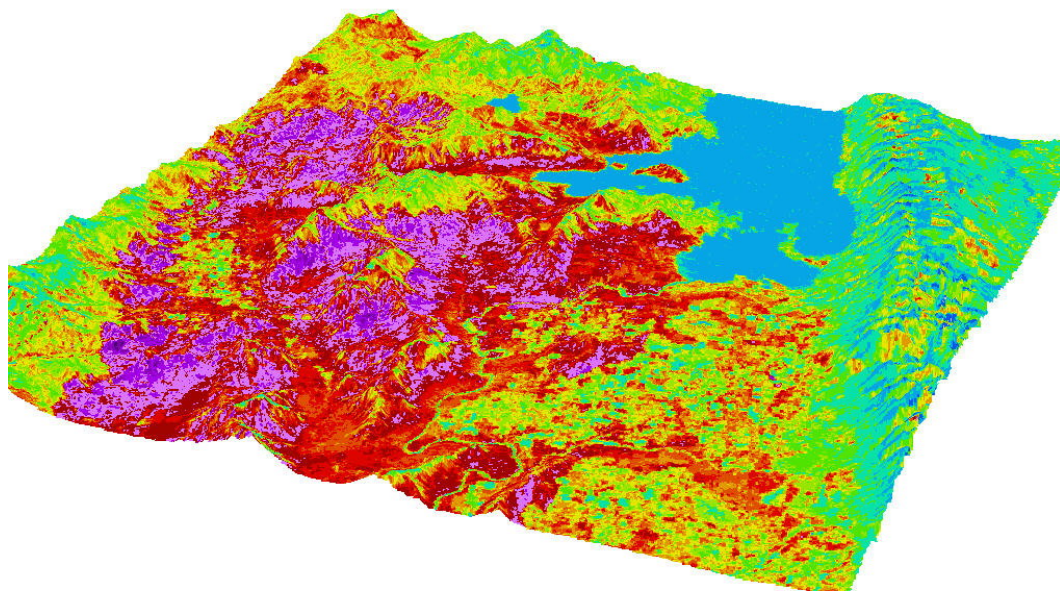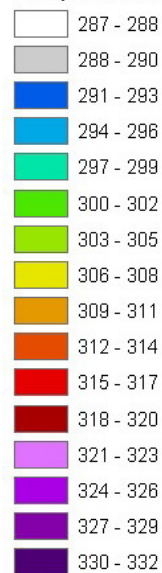
An experimental Vapor Pressure Deficit Map incorporating MODIS LST data is currently being produced for the Continental United States but is not yet available. Once the map is complete, it will be compared to the Vapor Pressure Deficit Map produced with the current algorithm to determine whether this is a course that should be followed in the future.

MODIS Land Surface Temperature 8-Day Composite, August 21 – 28, 2003

MODIS and ASTER LST Data over Flathead Lake, Montana

Temperature (Kelvin)

|	
☐	287 - 288
☐	288 - 290
■	291 - 293
■	294 - 296
■	297 - 299
■	300 - 302
■	303 - 305
■	306 - 308
■	309 - 311
■	312 - 314
■	315 - 317
■	318 - 320
■	321 - 323
■	324 - 326
■	327 - 329
■	330 - 332

ASTER Land Surface Temperature, August 21, 2003

Compute Services Team (CST)

Saxon Holbrook, Compute Service Team Manager (CST) & Network Administrator

Activities:

- Mastered 2001-02 MOD17A3 4.5 DVD for distribution at AGU.
- Enhanced backup of MODIS and other network data by doubling capacity and providing for redundant Legato servers.
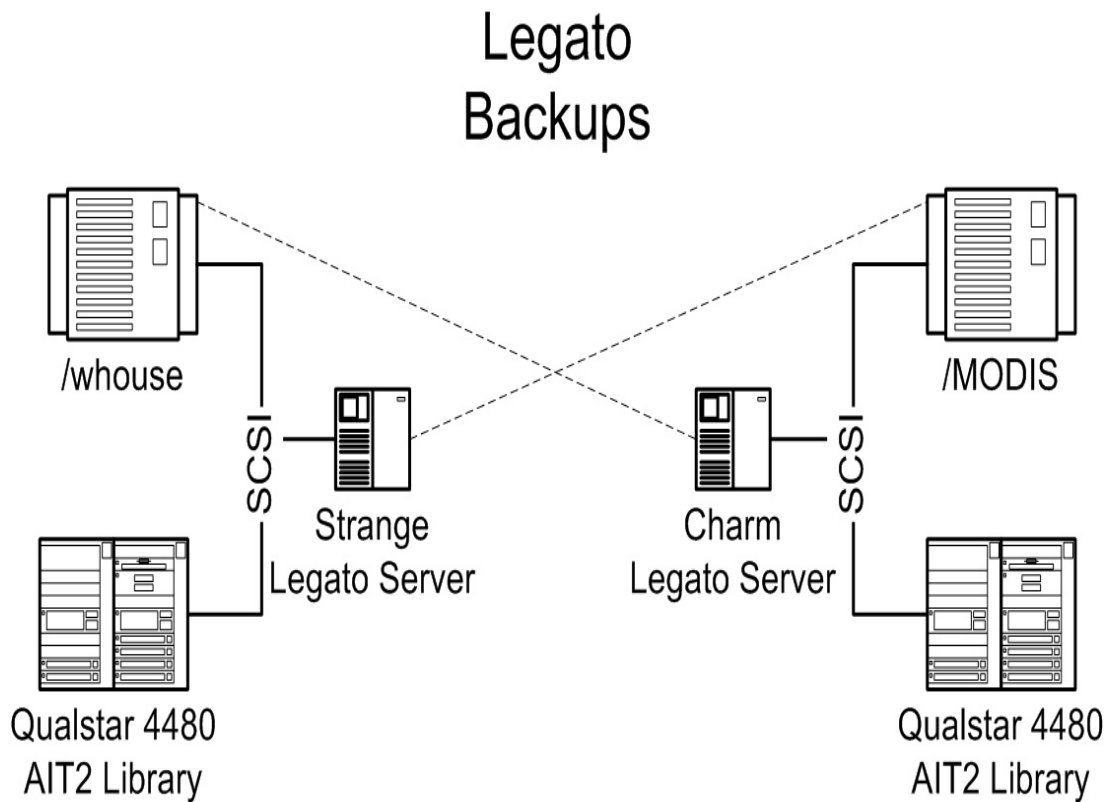
Multiple Legato Servers allow for local backup via direct connected SCSI and redundant backup via Gigabit (1000T) network connection.

- Managed and optimized network. Monitored Abilene I2 connection to EDC & Goddard. Implemented Redundant Network Connectivity to increase reliability and performance.
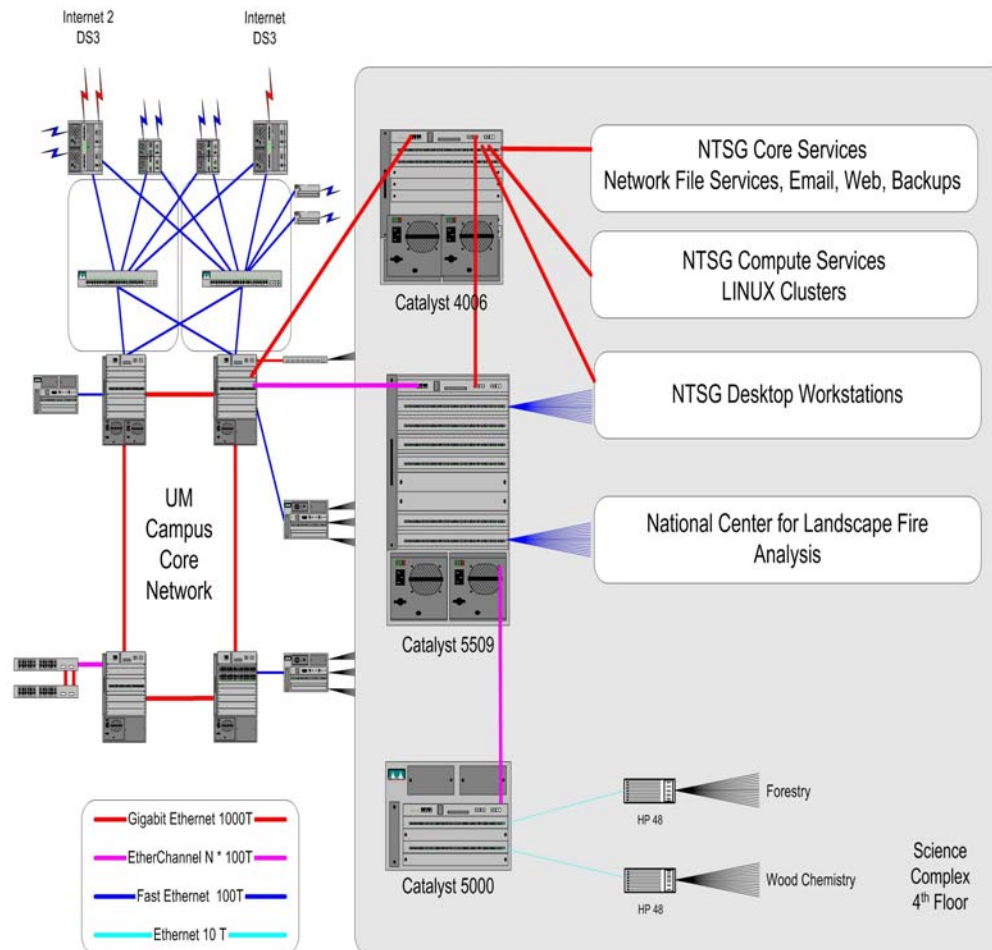
- Represented NTSG as a voting proxy for the ESIP Federation Meeting January 6-9, 2003 in Pasadena, CA. Participated in multiple breakout and hands on training sessions and presented a poster **High-ResNPP.ppt** (*file in .\images folder.*)
- Active member of the ESIP Federation Constitution and Bylaws Committee, Working Group for Peer Review and I regularly participate in the MODIS Cluster and ESTO Cluster.
- Prepared and Submitted Metrics to the ESIP Federation.
- Managed day-to-day activities and projects of the CST. CST Members during this period: Chad Bowker (Data Manager, Contract Ended June 1, 2003), Andrew Neuschwander (Linux System Admin), Andy Michaelis (Student Programmer, Graduated December 2003), Doug Wissenbach (Student Programmer, Graduated May 2003)

- Managed Software Environment and Licenses required for all activities, Windows Workstations and AIX Compute Environment.
- Maintained the DAYMET.org website. Preparing to transfer to P. Thornton at NCAR.

MODIS Related Meetings:

- ESIP Federation Meeting & Technical Workshops, Pasadena, CA, January 6-9, 2003

Andrew Neuschwander (LINUX System Administrator)

NTSG Images: http://images.ntsg.umt.edu

- Designed, debugged, and tested a new 'histbylc' tool. This tool computes histograms for MODIS data on a per land cover class basis. Worked closely with LLI on the development of this tool.
- Developed and produced automated histogram image generation to compliment raster imagery.
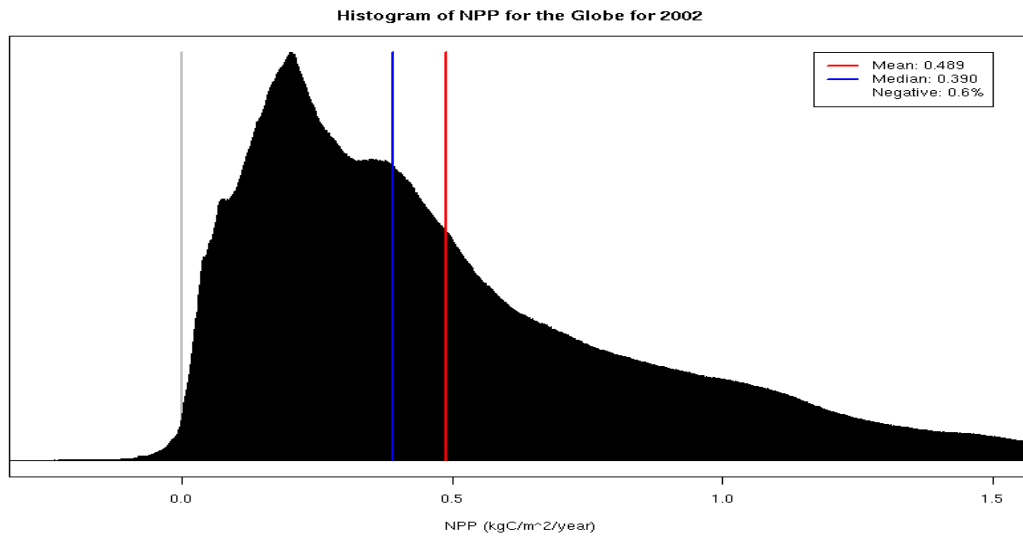
- Continued work (along with Andy) on the Modis Image tools.
- Produced two-year set of enhanced NPP images.
- Worked with Maosheng Zhao on enhanced NPP product.
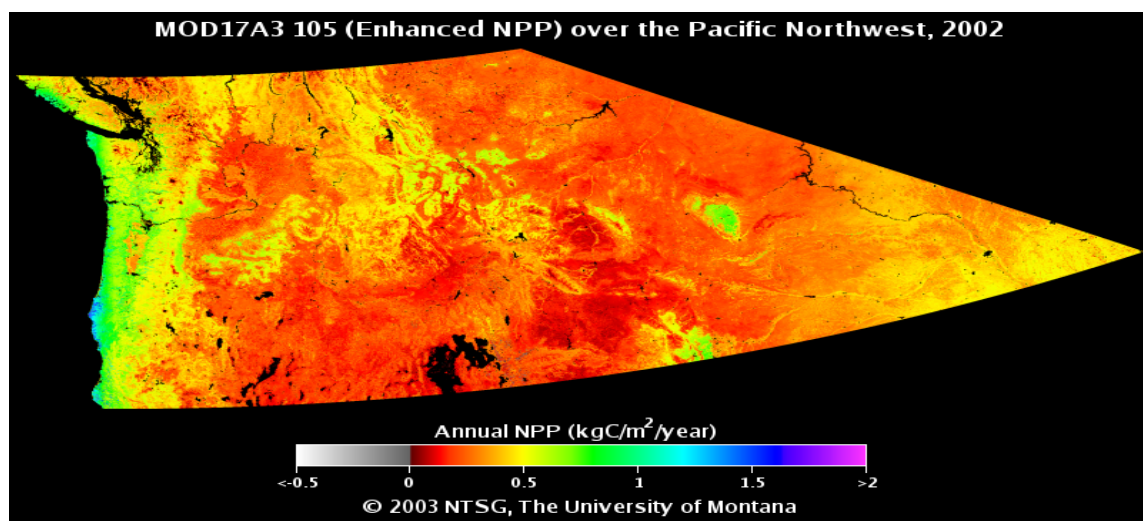
Data Management

- Now Manage: approx: 6TB of Data.
- Continued Data Management. Brought the Lab up to date on various data sets:
  - MODIS (selected products) Up to date MOD15/MOD17 from MODAPS.
  - NCDC Daily Summary, Global Surface Observations used in SOGS.
  - NRIS GIS data (partial mirror).
  - ORNL MODIS ASCII Subsets (complete automated mirror).
- Managed production and release of Enhanced NPP/GPP Product (MOD17 collection 4.5).

Other Projects & Tasks

- Continued to support the Compute Clusters and other compute resources.
- Continued to support Core lab IT services: web/email/ftp, etc.